International Journal of Research in Medical Sciences
Manna MMH et al. Int J Res Med Sci. 2025 Aug;13(8):3168-3173
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012
DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20252380

Original Research Article

Feasibility and evaluation of an automated software module for routine image-guided radiotherapy quality assurance: a clinical implementation and comparative study

M. Mahmudul H. Manna[1]*, Mohammad A. Islam[1], M. O. Rahman[2]

[1]Cancer Center, Combined Military Hospital (CMH), Dhaka, Bangladesh
[2]Department of Physics, Jahangirnagar University, Savar, Dhaka, Bangladesh

Received: 11 May 2025
Revised: 12 June 2025
Accepted: 03 July 2025

***Correspondence:**
M. Mahmudul H. Manna,
E-mail: hasansaccount@gmail.com

ABSTRACT

Background: Image-guided radiotherapy (IGRT) has revolutionized precision in radiotherapy treatments by ensuring accurate patient positioning and real-time anatomical localization. This study explores the clinical feasibility and utility of implementation of a web-based automated quality assurance (QA) software, for routine IGRT QA procedures.
Methods: Periodic IGRT QA procedures were conducted on a Varian TrueBeam linear accelerator (v2.5) with a web-based automated QA software platform. The kilovoltage (kV), megavoltage (MV), and cone beam computed tomography (CBCT) imaging systems were evaluated using appropriate phantoms namely, automated software company provided kV and MV phantom, Varian 6 Dot Marker, Varian MPC, TOR 18FG, Las Vegas, and Catphan® 604. Parameters such as geometric accuracy, spatial resolution, uniformity, low-contrast detectability, noise, slice thickness, and HU constancy were evaluated.
Results: The QA metrics met predefined baselines or AAPM TG-142 tolerances. The full QA process, including setup and analysis, was completed in 40–45 minutes. The software ensured consistent results with minimal manual intervention.
Conclusions: AQMS significantly improves the efficiency and consistency of routine IGRT QA. Its integration into clinical practice streamlines workflows and ensures compliance with QA standards, making it highly suitable for busy radiotherapy centers.

Keywords: Automation, IGRT, Quality assurance, Efficiency

INTRODUCTION

Radiation therapy (RT) aims to accurately administer a therapeutic or palliative dose to a precisely delineated target volume.[1] Modern radiotherapy techniques such as intensity modulated radiation therapy (IMRT), volumetric modulated arc therapy (VMAT), and stereotactic body radiotherapy (SBRT) requires high spatial and dosimetric accuracy to ensure effective tumour targeting while sparing healthy tissues.[2] Central to achieving this precision is image-guided radiotherapy (IGRT), which reduces geometrical uncertainties and facilitates accurate patient positioning through real-time anatomical visualization. Technologies such as kilovoltage (kV) and megavoltage (MV) planar imaging, along with cone beam computed tomography (CBCT), have become standard components of modern linear accelerators for this purpose.[3]

To maintain the reliability and performance of IGRT systems, robust and systematic quality assurance (QA) protocols are essential.[4] Alike other international organizations, The American Association of Physicists in Medicine (AAPM) Task Group 142 (TG-142) report provides comprehensive guidelines for the periodic

evaluation of imaging systems on medical linear accelerators, emphasizing parameters such as image quality, alignment accuracy, and geometric integrity.[5] The TG 198 report offers detailed procedural guidance for conducting the tests outlined in TG 142, along with estimates of the time and personnel required to complete them.[6] However, conventional IGRT QA methods often involve manual assessments that can be time-intensive and subject to inter-operator variability, increasing the risk of human error.[7]

Recent advancements in software automation offer promising solutions to streamline these QA workflows without compromising accuracy and adoption of any new technology and equipment requires a thorough QA program to ensure and oversee the system's performance characteristics.[8-11] Till to date several web-based automated QA software solutions are available in the market, each designed to streamline routine QA procedures and ensure compliance with standards like AAPM TG-142. These tools offer features such as automated data collection, real-time analysis, and centralized reporting.[12-14]

In this article, the commercial name of the specifically used web-based automated QA software platform have been deliberately omitted to maintain a neutral, non-promotional perspective. The focus remains on the general capabilities, functionalities, and clinical applications of the system rather than on endorsing or advertising the particular vendor or product. Hence the web-based automated QA software used in this work is named as "Automated QA Management Solutions" (AQMS). AQMS is designed to efficiently perform TG-142 compliant evaluations for kV, MV, and CBCT imaging systems.

This study evaluates the clinical utility and performance of AQMS in automating IGRT QA procedures. Specifically, it compares automated measurements with the software company provided QA tools and other in house available QA tools.

METHODS

This retrospective study was conducted on a Varian TrueBeam linear accelerator (v2.5) in Cancer Center, Combined Military Hospital (CMH), Dhaka, Bangladesh. Periodic IGRT QA tests were performed using AQMS modules connected to a local server. The AQMS is used to select QA modules, establish baseline data, and calculate results for routine IGRT QA tasks. Initially, the software generates baseline data ranges from DICOM images in alignment with the guidelines outlined in AAPM TG-142. For instance, when performing kV QA procedures, baseline values for image quality parameters are determined by averaging measurements from kV images acquired by a linear accelerator. Once these baselines are set, the software systematically analyses various QA tasks by comparing new measurements to the baseline data, thereby evaluating system performance and verifying adherence to established quality standards. While AQMS is versatile and applicable to different machine QA tasks, the key focus of this work is on IGRT QA. Data has been taken from AQMS database for the period of November 2023 to December 2024.

IGRT QA tools and tests

Several QA modules are provided into the AQMS which are highly essential for accurate and precise IGRT. For example, scaling ensures that the measurements recorded during QA tests accurately reflect the actual physical dimensions. Spatial resolution refers to the capacity of an imaging system to distinguish between small, closely spaced objects which is often reported in line pairs per millimetre (lp/mm). Uniformity ensures the CT simulator displays consistent Hounsfield units (HU) across a uniform area which is usually measured in water-equivalent material. Contrast evaluation refers to assessing how well different structures or tissues within the image can be distinguished from one another based on differences in their X-ray attenuation properties. Noise is the random variations in pixel values that do not correspond to actual differences in tissue density, which appear as graininess or speckle in the image.

In radiotherapy, it is critical to ensure that the system can produce high-quality images that accurately represent anatomical structures. Slice thickness evaluation refers to assessing the actual width of the imaged cross-sectional slice compared to the nominal (intended) slice thickness set during scanning. Low contrast resolution evaluation assesses the system's ability to distinguish between tissues with small differences in attenuation i.e., subtle variations in density. HU constancy evaluation in CT ensures that the CT number assigned to specific materials (like water, air, or bone) remains consistent and accurate over time and across scans.

Imaging and treatment coordinate coincidence

For daily Imaging and treatment coordinate coincidence verification Varian 6 Dot Marker is used. Varian machine performance check (MPC) phantom and its software is used weekly (Figure 1). For 6 Dot Marker displacement of lateral (mm), longitudinal (mm) and vertical (mm) is evaluated daily from a known shifted distance.

Planar kV imaging

AQMS kV QA tool and TOR 18FG phantom is used to perform different Planar kV imaging monthly QA tests which includes scaling, spatial resolution, uniformity, contrast and noise (Figure 2).

Planar MV imaging

AQMS MV QA tool and Las Vegas phantom is used to perform different Planar MV imaging monthly QA tests

which also includes scaling, spatial resolution, uniformity, contrast and noise (Figure 3).

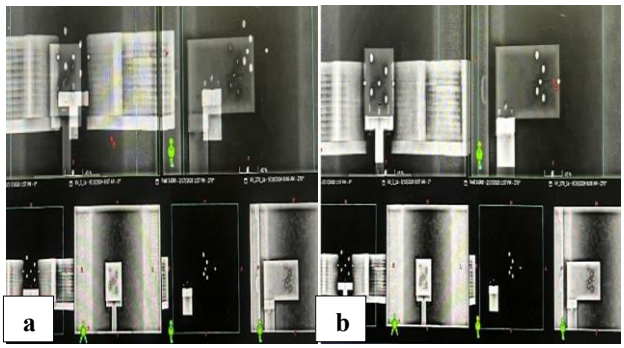

Figure 1: Imaging and treatment coordinate coincidence verification with 6 Dot marker, (a) before coincidence verification, and (b) after coincidence verification.

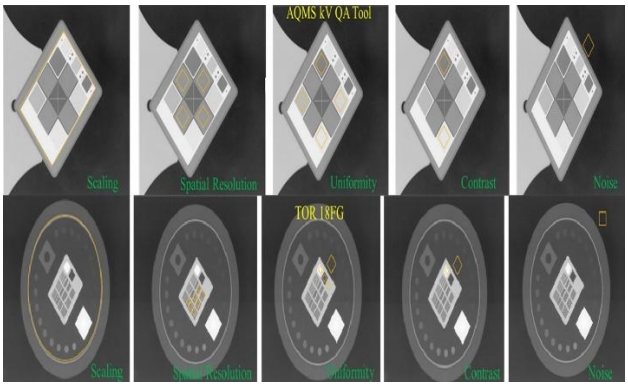

Figure 2: Planar kV imaging QA tests with AQMS kV QA Tool and TOR 18FG.

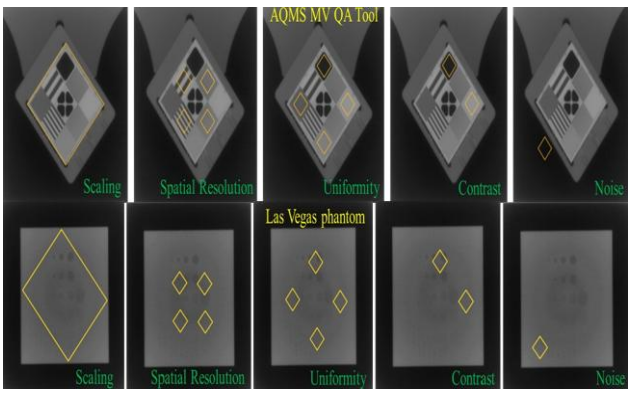

Figure 3: Planar MV imaging QA tests with AQMS MV QA tool and Las Vegas phantom.

CBCT QA

Catphan® 604 phantom has been used for different CBCT monthly QA tests which includes geometric distortion, spatial resolution, uniformity, contrast, noise, slice thickness, low contrast and HU constancy measurement of different inserts (Figure 4).

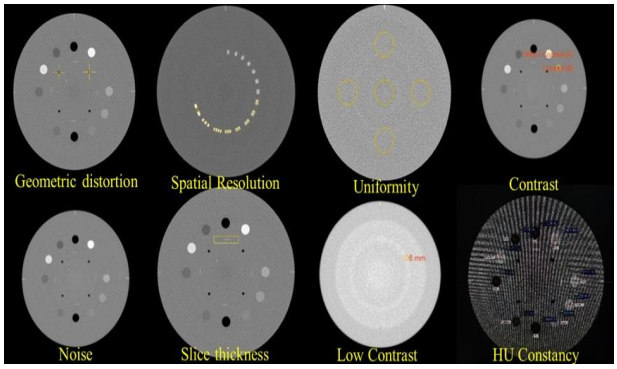

Figure 4: CBCT QA with Catphan® 604 phantom.

Statistical analysis

Statistical analyses are expressed as mean and standard deviations. Furthermore, paired *t*-test is conducted and a two-tailed p value of less than or equal to 0.05 was considered statistically significant. All statistical analyses are performed using IBM statistical package for the social sciences (SPSS) statistics version 20 (IBM Corp. IBM SPSS Statistics for Windows, Version 20.0.0 Armonk, NY: IBM Corp., 2011).

RESULTS

The QA metrics met established baselines or AAPM TG-142 tolerances. Each individual QA process, from setup to analysis, took 10–15 minutes to complete. The full QA process was completed in 45 minutes on average. The AQMS software provided consistent results with minimal manual input. Daily imaging and treatment coordinate coincidence verification test recommended by TG-142 is manually done and recorded. Automated MPC is done weekly to check all the parameters along with IGRT QA (Table 1).

Planar kV, MV and CBCT imaging tests are conducted monthly with either AQMS QA tools or other alternative phantoms to check consistency and variability. Usually the tests take 10-15 minutes for record and verifying. For Planar kV and MV imaging QA tests significant results are found as the baseline value of the AQMS is also different for different devices. In some cases, the correlation and t cannot be computed because the standard error of the difference is 0 (Tables 2 and 3).

Manual analysis of CBCT imaging QA elapsed a mean time of 35 min (range: 30–40 min) to complete and record. Most of the parameters of CBCT QA tests did not show a statistically significant difference between the manual analysis and AQMS results. For the AQMS, the generated results are passed compared to the baseline values and adhered to AAPM-TG 142 requirements. Results include statistical summaries (mean, standard deviation, paired t-test) for each QA parameter. All measured parameters were found within baseline tolerance ranges of AQMS as per TG-142 (Table 4).

Table 1: Imaging and treatment coordinate coincidence verification.

Parameters	6 Dot marker (observation-90)		MPC (observation-30)		Tolerance
	Mean	SD	Mean	SD	
Lateral (mm)	0.050	0.042	0.003	0.020	≤2 mm
Longitudinal (mm)	0.051	0.034	0.024	0.030	
Vertical (mm)	0.025	0.022	0.261	0.044	

Table 2: Planar kV imaging QA tests (observation-30).

Parameters	AQMS kV QA tool		TOR 18FG		P	Tolerance/baseline
	Mean	SD	Mean	SD		
Scaling (mm)	0.249	0.068	0.133	0.064	0.000	≤2 mm
Spatial resolution (lp/mm)	1.403	0.015	1.0	0.0	0.000	√
Uniformity (%)	99.757	0.568	99.253	0.048	0.001	√
Contrast (units)	0.5	0.0	0.861	0.003	0.000	√
Noise (units)	44.016	1.041	175.97	5.799	0.000	√

Table 3: Planar MV imaging QA tests (observation-30).

Parameters	AQMS kV QA tool		Las Vegas		P	Tolerance/baseline
	Mean	SD	Mean	SD		
Scaling (mm)	0.083	0.048	0.073	0.054	0.437	≤2 mm
Spatial resolution (lp/mm)	-1000000	0.0	-1000000	0.0	-	√
Uniformity (%)	90.507	2.745	88.303	0.094	0.001	√
Contrast (units)	0.864	0.008	-1.513	0.220	0.000	√
Noise (units)	0.0	0.0	0.0	0.0	-	√

Table 4: CBCT QA with Catphan® 604 phantom (observation-30) with AQMS and manual calculation.

Parameters	AQMS calculation		Manual calculation		P	Tolerance/baseline
	Mean	SD	Mean	SD		
Geometric distortion (mm)	-0.094	0.043	-0.088	0.038	0.012	√
Spatial resolution (lp/mm)	0.308	0.027	0.251	0.011	0.071	√
Uniformity (HU)	-5.441	0.966	-4.885	0.857	0.152	√
Contrast (units)	0.955	0.005	0.861	0.001	0.171	√
Noise (units)	14.381	2.005	12.002	1.032	0.054	√
Air (HU)	-997.591	1.111	-999.90	0.350	0.121	√
Teflon 'R' (HU)	959.168	5.744	1028	5.314	0.034	√
Delrin 'R' (HU)	349.699	5.433	318	6.478	0.105	√
Acrylic (HU)	108.898	3.613	108	3.321	0.052	√
Polystyrene (HU)	-49.587	2.735	-50	2.214	0.055	√
LDPE (HU)	-105.828	3.499	-95	2.987	0.030	√
PMP (HU)	-197.388	3.157	-174	3.398	0.062	√
20% bone (HU)	231.065	3.554	226	3.142	0.001	√
50% bone (HU)	740.322	5.272	768	4.687	0.034	√
Slice thickness (mm)	2.693	0.402	2.489	0.326	0.019	√
Low contrast (mm)	11.818	2.926	10.367	2.144	0.114	√

DISCUSSION

The implementation of AQMS significantly reduced the time required for conducting routine IGRT QA procedures while maintaining measurement accuracy. Compared to traditional manual or semi-automated methods, AQMS offers improved workflow efficiency and minimizes human error. This study compared AQMS QA tools with other vendor QA devices into the same software platform. This study could not conduct the annual QA of imaging dose due to the unavailability of required phantom and ion chamber.

The results demonstrate that AQMS is capable of providing precise and repeatable QA measurements across various imaging modalities. Compared to traditional

manual QA protocols, the software significantly reduces operational time and user dependence, thereby minimizing variability. Our results align with findings from the previous studies done by Dhoundiyal et al who evaluated the SunCheck™ Machine (SCM), a web-based QA platform and concluded that the automated QA software allows for accurate calculation and eliminates interobserver variation and human errors.[7] Also emphasizing that the automated QA system is an indispensable aspect of modern practice, especially in a progressively resource-limited setting.

Another study done by Bonanno et al concluded similarly about automation's benefits for consistency and efficiency.[8] They found that the AutoQA solution completed the monthly QA in 90 minutes, compared to 190 minutes required by the conventional approach.

Stambaugh et al demonstrated the development of a comprehensive TG-142 DQA process that utilized the SunCHECK machine (SCM) as the primary tool, while also incorporating machine performance check (MPC) as a valuable supplementary method for output verification.[12] Their study showed that the SCM approach took approximately 22 minutes, with a standard deviation of 6 minutes, whereas the MPC method reduced the duration to 15 minutes with a smaller standard deviation of 3 minutes. Although there was some overlap between the tests, those performed using SCM were more closely aligned with the TG-142 requirements, highlighting its relevance.

In contrast to using commercially available device and software, Eckhause et al developed analytical software tools for a QA program using both log files and electronic portal imaging device (EPID) measurements.[3] They conducted the automated QA test programme in eight institute and concluded that the results from standard tests across institutions can facilitate the identification of QA process and Linac changes. In line with this, Kerns et al standardised an autonomous QA system consists of a customized phantom, an optical imaging system, and a software to process the captured signals.[13] They found total measurement time was less than 10 minutes for all tests as a result of automation.

Limitations

This study presents data collected over 14 months from a single linear accelerator, accounting for the relatively small sample size. Automated imaging QA technology is newer to our country and gradually emerging. Comparative studies with other centers or with other commercially available similar technology may help us to further understand the advantages and drawbacks.

CONCLUSION

Notably, time savings are substantial and AQMS creates additional clinical availability for other QA or patient-related tasks. The centralized data repository on the AQMS server enhances traceability, auditing, and long-term data analysis. The AQMS software delivers precise calculations while removing interobserver variability and human error. With near-instant result availability, it offers a highly time-efficient solution. Efficiency evaluations, like the one presented here, guide optimal allocation of staff and time, helping to minimize waste. Such approaches are vital in modern clinical practice, particularly amid growing resource constraints.

ACKNOWLEDGEMENTS

Authors would like to thank the medical physicist and radiotherapy technologists team who gave their meaningful efforts in periodic IGRT QA procedure.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

1. Bissonnette JP, Balter PA, Lei D, Langen KM, Lovelock DM, Miften M, et al. Quality assurance for image-guided radiation therapy utilizing CT-based technologies: A report of the AAPM TG-179. Med Phys. 2012;39(4):1946-63.
2. Clivio A, Vanetti E, Nicolini G, Giaj-Levra N, Fogliata A, Cozzi L, et al. Evaluation of the Machine Performance Check application for TrueBeam Linac. Radiat Oncol. 2015;10(1):97.
3. Eckhause T, Al-Hallaq H, Ritter T, DeMarco J, Farrey K, Pawlicki T, et al. Automating linear accelerator quality assurance. Med Phys. 2015;42(12):6074-83.
4. Rafic M, Ravindran P. Evaluation of on-board imager cone beam CT Hounsfield units for treatment planning using rigid image registration. J Cancer Res Ther. 2015;11(4):690-6.
5. Klein EE, Hanley J, Bayouth J, Yin FF, Simon WE, Dresser S, et al. Task Group 142 report: Quality assurance of medical accelerators. Med Phys. 2009;36(9):4197-212.
6. Hanley J, Klein EE, Bayouth J, Chen J, McCullough E, Yaldo D, et al. AAPM Task Group 198 Report: An implementation guide for TG 142 quality assurance of medical accelerators. Med Phys. 2021;48(7):e830-49.
7. Dhoundiyal M, Sharma M, Singh D, Kumar S, Agarwal S, Gupta R, et al. Validation and efficiency evaluation of automated quality assurance software SunCHECK™ Machine for mechanical and dosimetric quality assurance. J Med Phys. 2024;49(2):311-5.
8. Bonanno E, Barbagallo M, Romano A, Fiorino C, Oliviero D, Puglisi R, et al. Use of an automated software module for monthly routine machine QA tests. J Instrum. 2023;18(07):T07010.
9. Yoo S, Yin FF, Kim J, Lee S, Woo MK, Chung J, et al. A quality assurance program for the on-board imagers. Med Phys. 2006;33(9):3451-63.

10. Chang Z, Bowsher J, Cai J, Yoo S, Wang Z, Adamson J, et al. Imaging system QA of a medical accelerator, Novalis Tx, for IGRT per TG 142: our 1 year experience. Med Phys. 2014;41(8):081708.
11. Stanley DN, Papanikolaou N, Gutiérrez AN. An evaluation of the stability of image-quality parameters of Varian on-board imaging (OBI) and EPID imaging systems. J Appl Clin Med Phys. 2014;15(4):4765.
12. Stambaugh C, Yancey J, Shukla U, Melhus C, Stambaugh N. Daily quality assurance efficiency evaluation using SunCHECK Machine and machine performance check. Cureus. 2023;15:e35695.
13. Jenkins CH, Naczynski DJ, Yu SJ, Yang Y, Xing L. Automating quality assurance of digital linear accelerators using a radioluminescent phosphor coated phantom and optical imaging. Med Phys. 2014;41(7):072802.
14. Martin G, Fogarty K, Egleston D, Howard L, Gilmore M. PO-1720 SunCHECK Machine, an automated QA software solution: A centre's 5-year experience evaluation. Radiother Oncol. 2021;161:S1445-6.

Cite this article as: Manna MMH, Islam MA, Rahman MO. Feasibility and evaluation of an automated software module for routine image-guided radiotherapy quality assurance: a clinical implementation and comparative study. Int J Res Med Sci 2025;13:3168-73.